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Abstract. This paper presents the need for specific curricula in order to address the training of specialists in the area of Interactive Critical Systems. Indeed, while curricula are usually built in order to produce specialists in one discipline (e.g. computer science) dealing with systems or products requires training in multiple disciplines. The area of Interactive Critical Systems requires deep knowledge in computer science, dependability, Human-Computer Interaction and safety engineering. We report in this paper how these various disciplines have been integrated in a master program at Université Toulouse III, France and highlight the carrier paths followed by the graduated students and how these carriers are oriented towards aeronautics and space application domains.

1 Introduction

Since the advent of personal computing, the average expertise of users in terms of computers science is constantly dropping. Accordingly, user interface usability (efficiency, effectiveness and satisfaction) has become increasingly important in software development in particularly because this aspect can determine the adoption or rejection of the entire software [1]. Nowadays, the user interface takes a very important share of design and development tasks in modern software development [4]. Aware of the fact that designers and developers need appropriate training to cope with users' needs and expectations about the user interface of interactive systems, the Association for Computing Machinery[1] (ACM) and the International Federation for Information processing (IFIP) hold permanent working groups for promoting the education on Human-Computer Interaction (HCI).

[1] ACM Special Interest Group on Computer Human Interaction :
http://www.sigchi.org/

The occurrence of HCI courses in undergraduate programs is essential to present concepts (e.g. usability, accessibility, User Experience [2]) and techniques (e.g. prototyping [7], user interface evaluation) necessary for designing user-centered interactive systems. In the last years there were increasing numbers of undergraduate programs in Computer Science that propose courses of Introduction to Human-Computer Interaction (HCI) in their curriculum. However, these courses rarely exceed 40 hours (in front of student), which is by far not enough to prepare students to work as usability professionals. However, this kind of course makes it possible for them to understand the underlying development process of User Centered approaches [5], to cooperate with specialists in that domain and to understand the costs and benefits of such approaches [2]. In order to cover this gap, specialized master 2 programs have been created in the last decade around the world (see the list of HCI programs provided by Gary Perlman [6]).

It goes without saying that the success of graduating programs in HCI is related to an increasing demand for professionals with a strong understanding of usability and user experience. The interests of the industry can easily be measured in terms of internship and job offers. However, there is a paradox: whilst some companies look for professionals with very specific skills (e.g. usability evaluation methods, development of multimodal interaction techniques, etc.) to fill a position in development teams, others companies have limited competencies in HCI in-house so that they recruit professionals to initiate a usability culture inside their organization. Moreover, graduate programs should cope with companies' expectations in terms of required technological background (e.g. mobile, Web, multimodal interfaces, etc.) and knowledge on the idiosyncrasy of the application domains (e.g. gaming, workspace applications, safety-critical systems, airspace, e-government, healthcare etc.).

2 The Basics of a Curriculum in HCI

Fig. 1 presents the map of HCI as it appears in the curriculum of HCI[2] proposed by ACM Special Interest Group on Computer Human Interaction. As stated in this curriculum, the area of HCI can be split in 4 main groups of content: (U) the use and context of computers, (H) human characteristics, (C) computer system and interface architecture, and (D) the development process.

As this curriculum has been developed in the early 90s it clearly represent an "old-fashioned" view of the domain of HCI but it is important to note that it is far away from obsolete as new development in the field can very easily positioned within this framework. One underlying assumption from this map is that there is one user interacting in a static way with a single computer with an input device being a mouse and one output device being a screen. The development process (section D) clearly exhibit's the iterative nature of development in order to address evolutions of user needs and improve usability through evaluations.

[2] `http://old.sigchi.org/cdg/cdg2.html` retrieved March 1st, 2013.

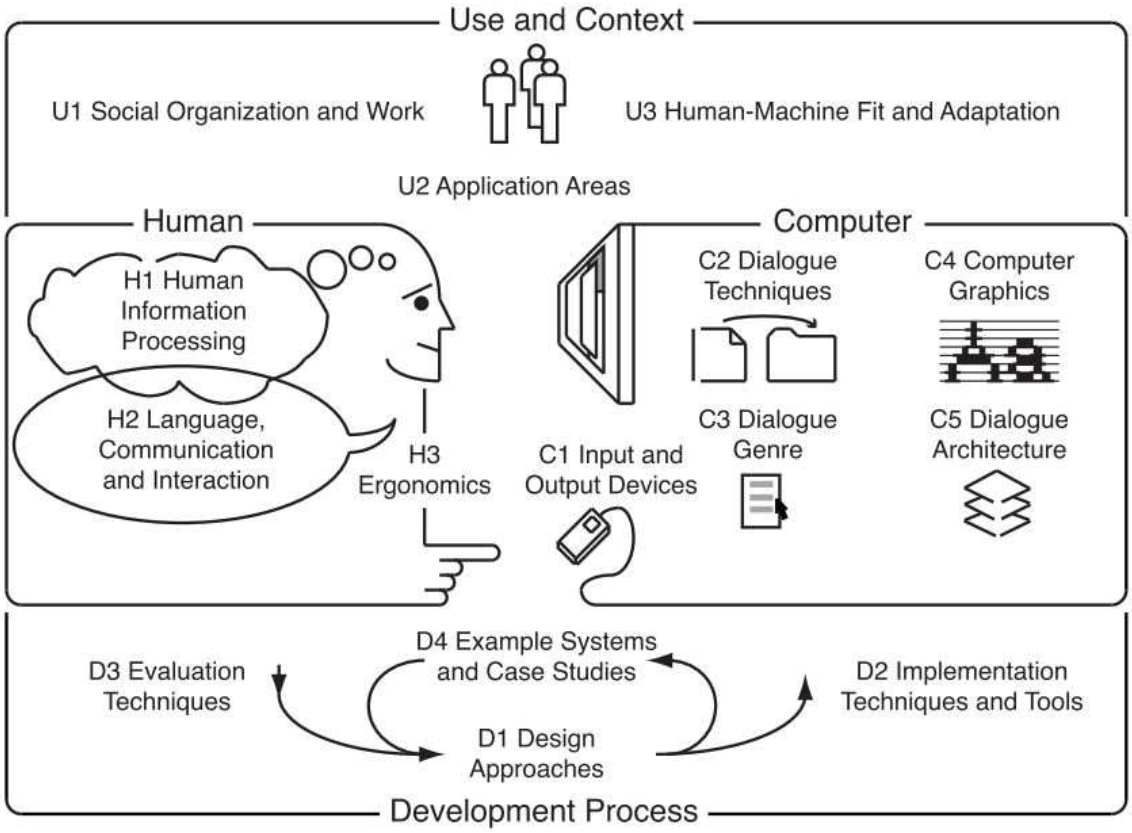

Fig. 1. Representation of the content of Human-Computer Interaction[1]

Current development in the area of HCI would propose evolutions to this map adding at least:

- For the computer side (C): the interaction with multiple combined input devices going beyond the mouse including multimodal input [12] (e.g. touch and multi-touch interactions) and multimedia output. Evolutions should also gather new technologies such as interaction on the move with mobile devices.
- For the Human side (H): interactions now take place mainly in a multi-user perspective including collaborative activities and social computing [13]. These capabilities have strong impacts on the computer aspects bringing in the perspectives of distributive systems together with privacy and security aspects [10] which usually conflict with usability [8] and user experience [15].
- For the development side (D): iterative processes have made their way in the area of software engineering with the trends of agile processes and extreme programming [14] however inclusion of usability aspects within them remains a challenge only addressed by researchers in the area of HCI [9].
- For the use and context (U): new interactions have spread in many contexts, environments and organizations due to the simultaneous distribution of computing devices at home and in the workplace.

3 The Requirements for Interactive Critical Systems

Taking into account the evolutions presented in the section above, this s
refining them when put in perspective with the requirements and needs
critical systems.

3.1 Requirements on the Computer Side (C)

Fig. 2 and Fig. 3 present two screenshots of the flight deck of the nev
aircraft (the Boeing 787). Fig. 2 demonstrates how new interaction tecl
made their way into the areas of safety critical system as multiple l
screens are available and interaction with them takes place though tra
on the middle lower part of the image.

Fig. 2. The Interactive Cockpit of new Civil Aircrafts (here Boeing 7

Fig. 3 is an image of the head-up display providing contextual info
pilots. This information has to be used by the pilot crew simultaneously
provided on the large displays.

Fig. 3. Close-up view of the Boeing 787 head up display

[3] Image from `http://www.aviationnews.eu/`

Future aircraft cockpits are likely to embed touch interactions which fits perfectly with the long lasting trend of embedding new interaction technologies in the area of critical systems when they reach the adequate level of maturity. We can even see that the speed of take up of interaction technologies is correlated to the level of criticality of the domain. In Air Traffic Management voice and tactile interactions were considered many years ago [16] and more recently for satellite ground segments [17].

3.2 Requirements on the Human Side (H)

Safety, privacy and security [18] have to be handled in a coherent way identifying potential conflicts early enough and ensuring their adequate treatment. Regulatory authorities in the various areas of critical systems add constraints to deal with issues related to argumentation and traceability of choices (see next section on development process). Addressing cooperation mechanisms for action and decision [20], human error [22], impact of automation [21] on human behavior are key elements of the overall resilience of the interactive critical system [19].

3.3 Requirements on the Development Process Side (D)

While HCI and discount software engineering approaches promote iterative processes producing rapidly modifiable artifacts, interactive critical systems call for systematic verifiable methods, processes and tools to provide means of assessing the resilience of the systems. New phases within the development process appear with prominent places such as traceability (as required in standards such as DO178B [24] and ESARR 6 [23]), training [25], barrier identifications and incident/accident analysis [19] and support for certification [24]. Some recent contributions have proposed complex processes trying to bridge this, at first glance, unbridgeable gaps [26].

3.4 Requirements on the Context and Use Side (U)

As for most of the interactive applications, interactive critical systems have to address different requirements depending on the application domain under consideration. For instance, certification is only required for systems with high risks to the citizen (such as nuclear power plants or large civil aircrafts) and is not present for military systems or satellite ground segments. However, some invariants remain including training of operators (as the systems are usually complex), means for addressing scalability and deep knowledge of the underlying engineering principles of these systems.

4 HCI Curriculum of the M2IHM Master Program

Previous section has in fact highlighted the needs for extensions of standard curriculum in HCI to encompass requirements from the safety critical area. We will show how such requirements have been deployed in a 2 years master on HCI programme at Université Toulouse III – Paul Sabatier.

The M2IHM[4] is a Master 2 program on Human-Computer Interaction that is jointly held by the University Paul Sabatier (UPS) and the National School of Civil Aviation (*Ecole Nationale d'Aviation Civile* - ENAC) in Toulouse, France. It is basically an option for the final year (i.e. 5th) of studies in Computer Science. The M2IHM, based in Toulouse, France, was created in September 2000 and it is the pioneer in HCI Education in France.

Students should apply for one of the 25 positions available, and, despite it is not officially an international master program, >15% of the students come from abroad (e.g. Germany, Spain, China, Tunisia). The main goal of the M2IHM is to teach HCI to students that follow a prior education on Computer Sciences. After following the M2IHM courses, students should also develop skills in HCI such as be able to: i) carry on projects using a user-centered design approach; ii) understand, chose and apply ergonomic recommendations whenever it is appropriate; iii) assess the qualities and defects of a user interface.

4.1 Organization and Content

The M2IHM program is deployed in two semesters (see Table 1). The first semesters is dedicated to courses whilst the second semesters is devoted to a group project called "*chef d'œuvre"* and an internship. The *"chef d'œuvre"* is an exploratory study during which the students can identify and assess different design option for a given interactive system, mainly proposed by industrial partners. This project is carried out by a group of 3-4 students and should cover all phases of the development process of an interactive system. It also must include a bibliographical survey. The internship occurs between 18-26 weeks and should be performed in an industrial context or with a research lab. The subject requires a prior approval from the pedagogical team.

Table 1. Teaching units of the M2IHM for 2011-2012

Semester 1 (total 457 hours)	
Teaching units	**Lessons / Contents**
UE 1 : Human factors	• Cognitive models of human processing • Software ergonomics • Task analysis and task modeling • Usability evaluation methods • Inquiry methods for HCI • Statistics applied to HCI • Accessibility and universal design • Requirement analysis for interactive systems
UE 2 : Methodologies for research in HCI	• Engineering interactive systems • Principles of empirical HCI research
UE 3 : Information visualization	• Information representation and display • 2D visualization and interaction
UE 4 : Design and development of user interfaces	• Development process of interactive systems • Prototyping and Agile methods

[4] *Master 2 Interaction Homme-Machine*: `http://www.masterihm.fr`

Table 1. (*continued*)

UE 5 : Interaction techniques and application domains	• Multimodal interaction techniques • Interaction techniques for the Web • Collaborative Systems • Mobile applications • 3D visualization and interaction • Multimedia systems
UE 6 : Programming techniques for interactive systems	• Component-based software for interactive systems (COM and NetBeans) • Participatory design • Web technologies • UML for HCI • Advanced programming for HCI
UE 7 : English and Project Management	• English (training for TOEIC/TOFFEL) • Project management

Semester 2	
Teaching units	**Lessons / Contents**
"*Chef d'œuvre*"	• Exploratory project
Internship	• Internship in the industry or research lab

4.2 Application Domains of Internships

The internships performed by the M2IHM student can be classified in five main application domains: aeronautics and aerospace, automotive, desktop applications, multimedia & Web, and new interaction techniques. As show by Fig. 4, 41% of internships performed from 2001 to 2010 occurred in the domain of aeronautics and aerospace which can be easily explained by the strong presence of companies like EADS/Airbus, Thales Avionics, Eurocopter, *Centre National d'Etudes Spatiales* (CNES). Desktop and office applications, which includes the development of collaborative systems, graphical editors and improvement of the ergonomic of existing applications, comes in second with 26% of internships.

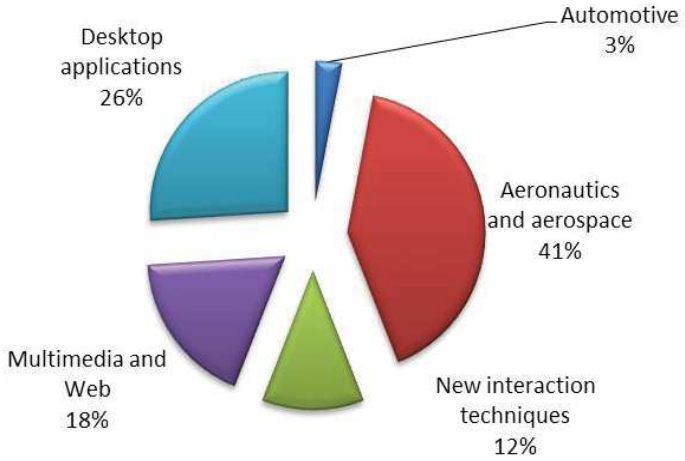

Fig. 4. Distribution of M2IHM internships from 2001 to 2010 (N = 209) accordingly to the application domain

Multimedia and Web applications sum up 18%. The category new interaction techniques encompass a large set of applications such as for the interactive TV, games, mobile systems, 3D and virtual reality, touchscreen, voice recognition... The automotive sector concerned 3% of internships.

Fig.5 presents the evolution of the internships over the years. It is interesting to notice that this evolution can be paralleled by changes in the market. For example, the automotive was responsible for 7 internships from 2002 to 2007 which correspond to the transfer of the R&D department of Siemens from Toulouse in 2008. The majority of internships occurs in the Toulouse area (>60%). In 15% of the cases, internships are performed abroad (ex. Australia, Austria, Canadá, Chile, Espanha, Japão, UK. The increasing number of internship offers in the aeronautics domain can also be paralleled to the expansion of recent programs such as the A380, A400M and A350 at Airbus (see Fig.5).

There is a large set of offers for internship concerning desktop applications but these are often seen as the last choice by students who often prefer new interaction techniques. Nonetheless, offers for internships with new interaction techniques are not so frequent. For instance, in 2010 the number of offers represented 28% (N=7, where 3 involving *multitouch*, 1 ambient systems/demotic, 2 games, 1 mobile applications), but looking back to previous years, the number of internships in this category was lower and it concerned different application domains (an iTV applications in 2009 and 3 virtual reality in 2008). A trend in this sector is thus difficult to assess.

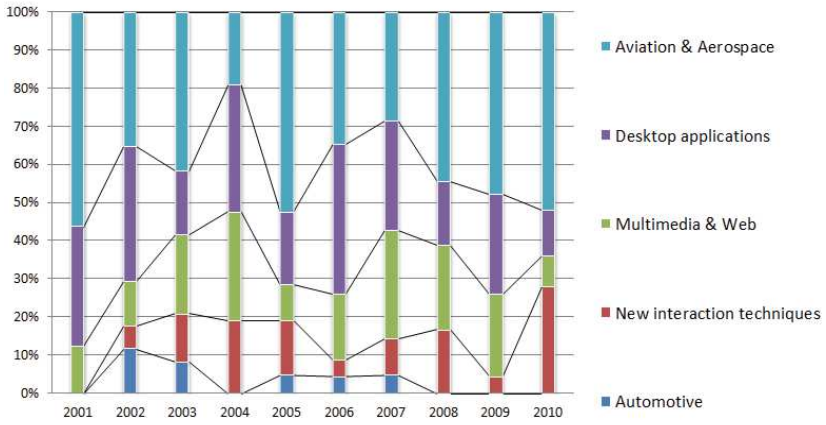

Fig. 5. Evolution of M2IHM internships from 2001 to 2010 (N= 209) according to the application domain

4.3 Interactive Critical Systems Content

The design driver around the tuning of the curriculum has been related to the fact that reducing current HCI training would damage significantly the knowledge of the students and their ability to work in the non-critical domains. For this reason we have decided to produce a double curriculum: one targeting at consumer products and the other one targeting at interactive critical systems. Each of the units presented above is thus split into 3 parts:

- A basic part containing the main principles and root knowledge of that area which is taught to all the students
- A part dedicated to the critical systems requirements addressing issues related to training, certification, human error, development standards, …
- A part dedicated to the consumer product market focusing on hedonic properties of user experience, design, large scale usability testing, ….

5 Conclusion and Future Work

This paper has presented the rationale for deep tuning of HCI curriculum when specific application domains are considered. We have tried to demonstrate that interactive critical systems require specific attentions and specific qualification in order to be designed and implemented in conformance with regulatory authorities that sometimes conflict and are incompatible with mainstream HCI knowledge and practice.

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